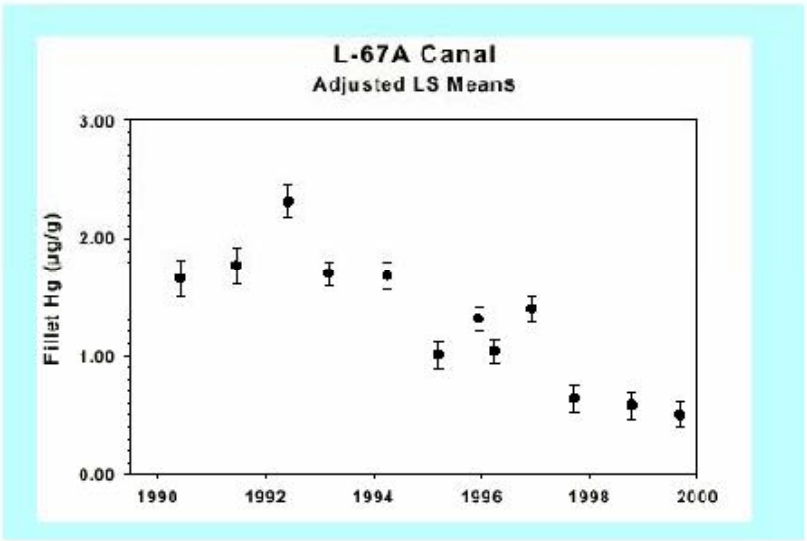
Chapter 7 - OCCURENCE AND IMPACT OF MERCURY IN NJ'S ENVIRONMENTAL MEDIA

A. Introduction

Mercury in the NJ environment is derived from both natural and anthropogenic sources. Based on various estimates, from 67% to about 80% of the yearly total global input of the mercury in air, water, soil, and food chain is derived directly or indirectly from human activities, both within NJ and elsewhere (Mason and Fitzgerald 1994). The relative contribution of in-state sources vs. regional/global sources to NJ's mercury load has been estimated to be about 67% from regional/global sources (NESCAUM et al. 1998). Other studies suggest that 50% of wet mercury deposition may be accounted for by local or regional sources (EPRI 1994; Bullock et al. 1998). Careful management of mercury sources through reduced use, emission controls, and retirement can reduce the inputs greatly. However, due to the complexity of mercury cycling in environmental media, there will be an inevitable time lag between the reduction of mercury releases to the environment and the lowering of the concentrations in any particular medium such as fish. Some media, particularly air, will reflect the changes more quickly than others, such as sediments. The observations in Florida that reducing mercury emissions from power plants resulted in reduced mercury levels in fish and fish-eating birds in less than a decade is a basis for optimism that mercury reduction will be beneficial quickly (see Figure 2.4). This chapter provides information on mercury concentrations in NJ's environmental media and describes the actions being taken to evaluate environmental mercury.

Figure 2.4. Changes in Mercury Concentration in Tissue of Largemouth Bass in a Florida Everglades Location in Conjunction with Reductions of Emissions of Mercury from Local Sources.



Mercury in fillets of age-standardized largemouth bass in Everglades Canal L-67 (Lange et al., 2000). Adjusted least square means.

B. Mercury in Air

Several studies from various parts of the world have measured gaseous mercury in air in the range of 1 to 6 ng/m^3 (ATSDR 1999a; Fitzgerald 1995) with higher levels measured near specific sources (ATSDR 1999a). In the Report to Congress (USEPA 1997a) a value of 1.6 ng/m^3 was used to represent background concentrations of elemental mercury in the air. There are no reliable measurements of mercury in NJ's air that can be considered representative of the state background.

1. Air Deposition Studies

The Northeast Mercury Report (NESCAUM et al. 1998), using an EPA dispersion model (USEPA 1997a), estimated that deposition in NJ exceeds 30 µg/m^2/year. Research conducted by the NJDEP Division of Science, Research and Technology (Stevenson et al. 1995) found that mercury levels in precipitation and air are elevated above background in certain regions of the state. Levels measured ranged from 5 to 94 ng/L in precipitation, with the higher values in urban areas and lower values in undeveloped, forested areas. A recently established (1998) air monitoring network, the NJ Atmospheric Deposition Network (NJADN), is beginning to provide data on mercury in ambient air and mercury wet deposition. The NJADN was established to measure the amount of nutrients, organics and metals, including mercury, in particles in air and in rain to assess potential impacts of deposition, particularly on water resources. NJADN sites were chosen to provide data on impacts to sensitive watershed management areas and to help determine the extent of the contribution of out-of-state sources of pollution to deposition in NJ. Only total mercury is being analyzed in the samples collected as part of the network.

The sum of wet deposition and dry deposition gives a total deposition value expressed in units of micrograms per square meter per year (µg/m^2/year). Deposition values can be calculated for wet deposition (rain, snow and fog) by measuring aqueous mercury concentrations (µg/L) and multiplying by the volume of sample collected. Estimation of dry deposition is more difficult and subject to greater uncertainty, and estimates of the contribution of dry to total deposition range from less than 10% to nearly 50%. The concentration of various mercury species in air samples can be used to infer the amount of mercury in dry deposition.

The concentrations of mercury in NJ rain generally range from 8 to 20 nanograms per liter (ng/L), and show considerable intra-annual variability. These temporal fluctuations often appear to be statewide trends, and mercury concentrations in rain at the four sites generally vary over fairly narrow ranges for a given sampling period. Volume-weighted mercury concentrations in rain are highest in summer and lowest in spring, a seasonal pattern that may reflect additional sources of mercury to the atmosphere, higher precipitation amounts in summer or higher mercury oxidation rates in summer. Annual volume-weighted mercury concentrations in NJ ranged from 13 ng/L in New Brunswick to 15 ng/L in Camden. These values are generally higher than those measured at other eastcoast and Midwest locations but are comparable to mercury concentrations in rain measured around the Chesapeake Bay. Annual wet mercury fluxes were broadly similar across NJ and were similar to those measured in Maryland. Although regional sources and meteorology affect the variability of mercury concentrations in East Coast rain, lower concentrations have been noted in rural areas.

Table 2.8. Volume-Weighted Mean Concentration and Annual Flux of Total Mercury in NJ and in Other Eastern States (from Eisenreich and Reinfelder 2001).

Site	Volume-weighted Average (ng/L)	Annual Flux ($\mu g/m^2/yr$)	
NJ			
New Brunswick	13	14	
Jersey City (Liberty Science Center)	15	14	
Pinelands Research Center	12	14	
Camden	15	18	
OTHER SITES			
Chesapeake Bay (1995-99)	15	14	
Baltimore, MD (1996)	20	30	
Lake Champlain, NY/VT (1994)	6	8	
Lewes, DE (1996)	8	10	
Cambria County, South Central PA (1997-99)	10	10	
Tioga County, North Central PA (1997-99)	8	7	
Lake Michigan (1995)	10	8	
Little Rock Lake, WI (1989-90)	6	9	

2. Summary and Conclusions

On the basis of these preliminary NJ data from the NJADN, the wet deposition of mercury averages about 15 $\mu g/m^2$/year. This is higher than values reported elsewhere in the east, except for the Chesapeake Bay area and are higher than the national average of 10 $\mu g/m^2$/year (Sweet et al. 1999). Higher deposition rates in industrialized, highly populated areas of the East, such as NJ and the Chesapeake Bay region, suggest that local sources are important contributors to total deposition.

C. Mercury in Ground Water

1. Introduction

Drinking water is a direct route of human exposure to mercury. To address this important route of exposure, a drinking water standard or "maximum contaminant level" (MCL) of 2 micrograms per liter [2 µg/L or 2 parts per billion (2 ppb)] has been set by USEPA and adopted by NJDEP for inorganic mercury.

In Southern NJ, mercury has been identified in ground water at many locations. It is estimated that there are approximately 400,000 private wells in NJ serving approximately 1.5 million people (13% of the population). Private wells are required to be tested for a limited number of parameters (not including mercury) when the wells are drilled, but thereafter no regular monitoring is currently required. Some local health departments have adopted ordinances that require comprehensive testing of the well when there is a real estate transfer. As of December 2000, only Atlantic and Ocean Counties required testing private wells for mercury during such transactions. A new private well testing bill has been passed in NJ. The

bill will require statewide testing of water from private wells upon the sale of a home. While mercury is not included in the statewide testing requirements, it may be included in counties where prior regional testing has shown it to occur in well water.

2. Improved Analytic Techniques

As with air, improved understanding of low-level mercury concentrations has depended on improved analytical techniques and technology. The standard cold-vapor atomic absorption spectrometry protocol for total mercury in water yields a method detection limit of about 0.1 µg/L. However, pristine ground water can have concentrations of less than 5 ng/L (0.005 µg/L or 0.005 ppb). Therefore, the standard method is not adequate for measuring background levels of mercury.

The Skidaway Institute of Oceanography conducted a joint study with NJDEP to estimate background levels and to identify the species of mercury present in the ground water (Murphy et al. 1994; Windom & Smith 1992).

Water samples from known contaminated areas (n=16) as well as from relatively pristine areas of Southern NJ (n=62) were analyzed using the standard cold-vapor technique, an improved cold-vapor technique and an isotope dilution technique for analysis of total, volatile and reactive mercury species (Hg^{++}). A gas chromatographic method was employed for the determination of organic mercury.

The newer methods were found to be more sensitive than the standard method for characterizing background mercury levels in ground water in the range of 0.001 to 0.040 µg/L (inorganic mercury, probably mercuric chloride, was the predominant form of mercury). Volatile mercury (presumably elemental Hg) comprised approximately 10% of the total mercury. Organic mercury comprised less than 3% of the total mercury.

3. Occurrence and Sources of Mercury in Wells

The mercury in the contaminated wells is presumed to come from anthropogenic rather than natural sources. Data on the mercury concentration in rocks, which are a source of the Kirkwood-Cohansey sediments, and in soils overlying the Cohansey Sand reveal a natural background concentration of approximately 10 ng/g (10 ppb). Moreover, glauconite, the only mineral in the NJ Coastal Plain known to contain mercury, is virtually absent from the Kirkwood-Cohansey aquifer formation. Based on this information and a review of existing literature conducted in 1992, the NJ Geological Survey concluded that the mercury found in private well water in NJ is unlikely to be naturally-occurring (Dooley 1992).

NJDEP has been working with the US Geological Survey on a number of investigations. One of the first exercises to determine potential sources of mercury was to assemble all the available data into one master database. Data for mercury by county as of 1993 presented in Table 2.9. Comparing the data with information from other databases, such as locations of point sources and industries, and using the Geological Information System (GIS), USGS sought to find patterns to the contamination cases in an attempt to offer suggestions as to the sources of the contamination. A report, published in 1997, (Barringer et al. 1997) described six hypotheses to explain the mercury contamination. They were: 1) sampling or laboratory error; 2) atmospheric deposition; 3) household sources such as paint; 4) past use of mercurial pesticides; 5) point sources such as landfills; and 6) constituents of well pumps. While ruling

out sampling/laboratory error and consitutents of well pumps, the USGS continues to investigate the other possible sources of mercury to wells.

Table 2.9. Distribution of Total Mercury Concentrations in NJ Wells by County (From Barringer et al. 1997: Reporting on Data Collected from County Health Departments and NJDEP Before 1993).

County	# wells sampled	# wells > MCL of 2 : g/L	Median (: g/L)	Range (: g/L)
Atlantic	1,543	202	0.28	<0.01-34.5
Burlington	6	1	<0.01	<0.01-3.53
Camden	472	21	<0.50	<0.1-21.7
Cumberland	82	9	<1.00	<0.1-14
Gloucester	33	8	<0.20	<0.2-20.6
Ocean	51	19	1.10	<0.2-17
Salem	52	6	0.50	<0.2-42
Total	2,239	266	0.40	<0.01-42

Information on mercury concentrations in private potable well samples is maintained by local or county health departments. Since the 1997 USGS report, additional private wells have been monitored for mercury. Mercury has been detected in additional wells throughout southern NJ. As of 1999, there are approximately 400 wells located in 71 discrete residential areas in the state where at least one well contains mercury above 2 ug/L (see Figure 2.5). Gloucester County has initiated two programs for mercury monitoring. The County Health Department has offered to have any resident's well water tested for mercury. Almost 800 wells have been tested as a result of this program, with approximately 8% showing mercury levels above the drinking water standard of 2 μg/L. In addition to this, Gloucester County is designing an intensive monitoring campaign to sample water from 1000 randomly selected wells around the county. This will represent a random study and should help county officials better delineate the geographical extent of mercury contamination in their county.

Ocean County reports data from over 23,000 wells of which less than 1% contained mercury above the drinking water standard. Sampling of 240 wells in Hunterdon County in northern NJ indicate that mercury is not a problem in potable wells there – there were no exceedances of the MCL. In fact, no mercury was detected in these samples. The method detection limit was 0.04 μg/L .

A second phase of the USGS work (Barringer & MacLeod DRAFT) included analyses of tritium and helium in order to estimate the age of the ground water. Water containing elevated mercury concentrations appears to have been recharged to the aquifer between 10

and 55 years before the sampling date, or from 1938 to 1983. This is important information in that it elucidates the time of contamination to the aquifer. It indicates that the contamination is probably not recent.

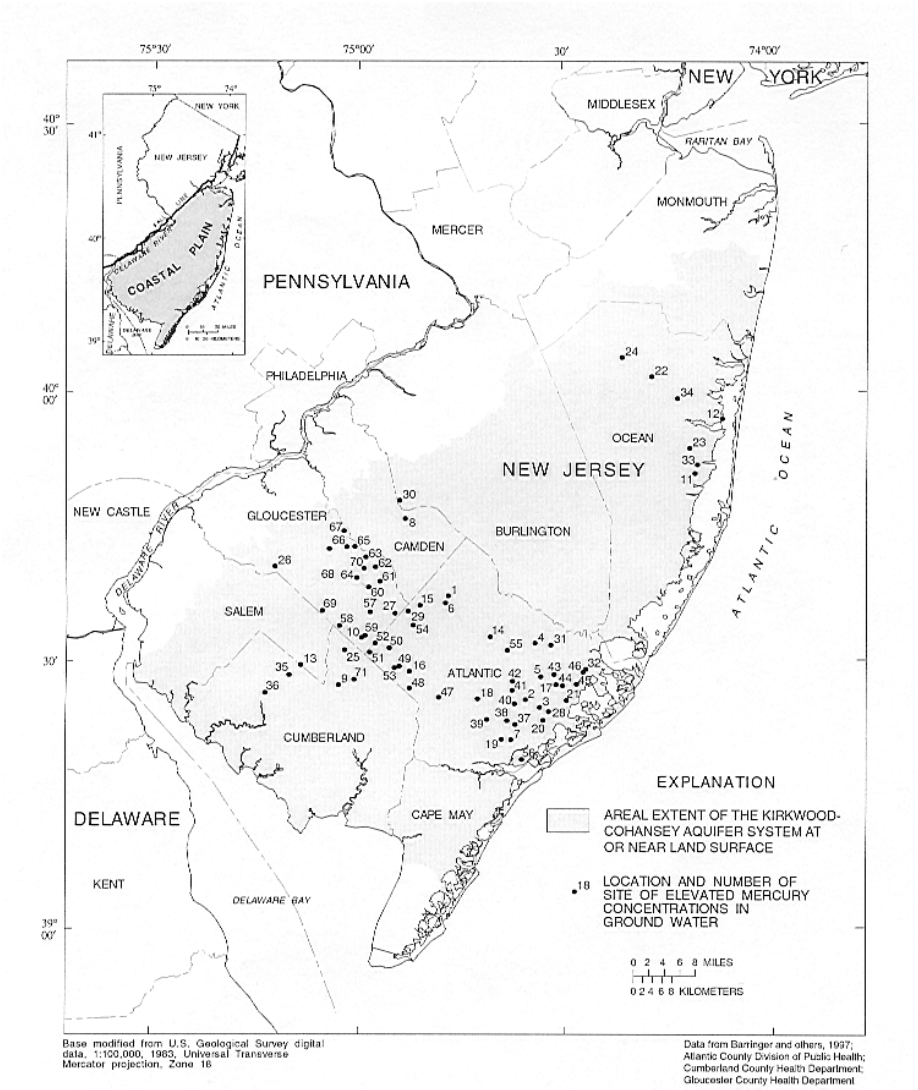


Figure 2.5. Locations of 71 Areas Where at Least One Well Contained Mercury Concentrations Above 2 ug/L. (Inset Map Shows Location of the New Jersey Coastal Plain.)

NJDEP continues to conduct and collaborate in studies investigating the issue of mercury in ground water. In 1998, NJDEP contracted USGS to conduct a two-year, multi-media mercury study to investigate the influence of land use on mercury contamination of ground water and the potential of mercury-contaminated ground water to discharge into surface water systems. The study is currently underway.

4. Reducing Mercury in Private Wells

As a result of finding mercury in well water, NJDEP sought methods of water treatment to install on impacted wells in order to reduce exposure to mercury. A study was performed by NJDEP staff to investigate the efficacy and cost of several types of point-of-entry treatment systems (POET systems) (Sites 1994). Data were collected over a three-year period from six different types of POET systems. Results of the project showed that bi-metallic type units were reliable and consistent at reducing the mercury to levels below the MCL. Wherever feasible, NJDEP recommends that homes with contaminated private wells be connected to community water systems. However, in some instances, this is not feasible, and a POET system is the only way to eliminate exposure to the contaminated water.

5. Summary and Conclusions

Depending on the particular county, approximately 0-13% of wells sampled (selected non-randomly) exceeded the Maximum Contaminant Level (MCL) of 2 ppb for mercury. This contamination appears to be confined to the Kirkwood-Cohansey aquifer and is unlikely to result from natural sources. Mercury in these wells is mostly in the form of mercury salts but small amounts of volatile (probably elemental) mercury have also been detected and raise potential concerns for inhalation during showering. Homes served by wells with mercury levels exceeding the MCL have been connected to community water supplies or supplied with individual point-of-entry (POET) systems.

D. Public (Community and Non-Community) Water Supplies

The NJDEP requires that public water systems, both community and noncommunity, monitor for mercury at different sampling intervals based on the type of water system and the source of the drinking water. At the end of 1997, there were 612 active community water systems (CWS) in NJ. A CWS serves at least 25 year-round residents or has 15 or more service connections (e.g., municipality). The 612 CWS serve approximately 87% of the State's estimated population, with 51% of the population being serviced by surface water systems and 49% by ground water systems. At the end of 1997, there were 4,100 active non-community systems in NJ. A non-community water system generally serves a nonresidential (i.e., an institutional) population. All but three of the NJ non-community systems utilize ground water sources.

Surface water systems monitor annually for inorganics including mercury, and ground water systems monitor every three years for mercury. Systems that exceed the MCL (either in a single sample or with the average of the original and repeat sample) must immediately begin quarterly monitoring. Systems must continue to monitor quarterly until analytical results show mercury to be "reliably and consistently" below the MCL. Ground water systems must take a minimum of two samples and surface water systems must take a minimum of four samples after the last analytical result above the MCL before monitoring frequency is reduced back to the base requirement (i.e., annually for surface water and every three years for ground water systems). The NJDEP Bureau of Safe Drinking Water (BSDW) maintains this data in a database on mercury results reported by community water systems and noncommunity water systems throughout the State.

Over 4,000 public water system samples have been analyzed for mercury since 1993 (Table 2.10). In 2000, only three systems have been issued MCL violations for mercury. A violation for mercury occurs when the mercury level in the original sample, or the average of

the original and confirmation samples, is higher than 2 ppb. In general, mercury does not appear to be a problem in community or noncommunity water systems in NJ.

Table 2.10. Mercury in Public Water Supplies (Based on Data From 1993 to 2000).

	Community Water Systems	Noncommunity Water Systems
Total number of systems in NJ (as of end of 1997)	612	4100
# samples with mercury detections	383	185
# systems with mercury detections	169	133
# systems with mercury > 2 µg/L in at least one sample	11	13
Average of detected levels, µg/L	0.76*	1.0*
Median of detected levels, µg/L	0.40*	0.33*
Range of detected levels, µg/L	0.1 – 8.0	0.04 – 10

**Detection limits for mercury during the time period ranged 0.04 to 2 ppb.*

E. Mercury in Surface Water

1. Introduction

Before 2001, Surface Water Quality Criteria applicable to NJ for mercury for freshwater were 2.1 µg/L (acute ecological effects; as dissolved Hg) and 0.012 µg/L (chronic ecological effects based on 30 days; as total recoverable Hg). For saltwater, the criteria are 1.8 µg/L (acute; as dissolved Hg) and 0.025 µg/L (chronic; as total recoverable Hg). The NJ human health criterion for total mercury in freshwater is 0.14 ꞉g/L. Currently, there are no sediment criteria available for NJ. In January 2001, the US EPA announced a new surface water criterion for methylmercury based on fish tissue concentrations of 0.3 µg/g. The corresponding concentration of mercury or MeHg in water is based on waterbody-specific modeling of chemical conversion, uptake and bioaccumulation (US EPA, 2001). NJ has not yet developed an approach for applying this fish-based criterion to the corresponding concentration of mercury in any specific waterbody. Therefore, in this report, comparison will be made to the former criteria.

2. Freshwater

The Ambient Stream Monitoring Network (ASMN) has operated cooperatively by NJDEP and USGS since the early 1970's. Until 1997, mercury data were collected on a rotating schedule at two-thirds of the 79 stations each year. In 1995, modified Clean Methods sampling techniques were implemented, resulting in improved data quality. In 1997, the number of sampling stations was increased to 115, with mercury sampled once a year at each

of 40 stations (two per Watershed Management Area) selected at random from the set of approximately 820 benthic macroinvertebrate monitoring stations located in freshwater streams. In addition, in 1998, the NJDEP began monitoring 50 stream segments or estuarine areas identified on the basis of measured or modeled exceedances of applicable surface water quality criteria for mercury (NJDEP 1998). At these locations, Clean Methods techniques are used for sampling total recoverable and dissolved mercury for three consecutive days under stable baseflow conditions. Data for these locations are currently being assessed and are not reported here. The data for mercury for 1990 - 2000 are summarized in Table 2.11.

a. Summary and Conclusions

Although the data are somewhat difficult to interpret due to changes in the number of sampling locations as well as changes in the detection limit, it appears that the occurrence of elevated mercury in NJ streams has decreased since the 1990-1994 period. However, with the current data, it is not possible to assess the potential for ecological impact relative to chronic effects on aquatic life.

3. Estuarine and Marine Waters

The coastal waters of NJ are represented in three National Estuary Programs: NY-NJ Harbor Estuary Program and the Bight Restoration Plan (HEP), Delaware Estuary Program (DELEP), and the Barnegat Bay Estuary Program (BBEP). Both the HEP and DELEP have Comprehensive

Table 2.11. Number of Stream Samples Exceeding Various Criteria Values.

Sampling Period	Number of Stations Sampled	Percent of Stations Exceeding the Chronic Aquatic Life Surface Water Criterion (0.012 : g/L total Hg)	Percent of Stations Exceeding Human Health Surface Water Criterion (0.14 µg/L total Hg)	Percent of Stations Exceeding the Acute Aquatic Life Surface Water Criterion (2.1 : g/L dissolved Hg)
1990-1994	79	not reported	20%	not reported
1/95-9/97	81	[a]	6%	0%
10/97-10/00[b]	114 (82 stations evaluated with method detection limit = 0.1 : g/L)[b]	[a]	0% [c]	0%

a. Samples were analyzed as total recoverable mercury and the method detection limit was 0.1 or 0.3 : g/L. Therefore, the chronic aquatic life criterion could not be evaluated.

b. The method detection limit for the period 1998-1999 was 0.1 : g/L. The method detection limit during 2000 was 0.3 : g/L.

c. Based on 82 stations sampled in 1998-1999 with a method detection limit of 0.1 µg/L

Conservation and Management Plans (NJDEP 1996). In the NY-NJ Harbor Estuary, mercury exceeds the water quality criterion (for protection against chronic ecological effects) of 0.025 µg/L virtually throughout the estuary (NJDEP 1999). The new EPA Surface Water Criterion for methylmercury (human health) has not yet been applied to NJ waters.

The NJ Harbor Dischargers Group (NJHDG), comprised of eleven sewerage authorities in the Harbor area, prepared a report entitled "Summary of the Phase I Metal Sampling and Analysis Program for the NJ Component of the NY-NJ Harbor Estuary Program" (Marsh

1996, with supplement). The report for the Hackensack River below Oradell Dam, the Passaic River below the Dundee Dam, Newark Bay, Raritan Bay and the Raritan River below Fieldsville Dam indicated that all of these waterbodies are "water quality-limited" (higher than or close to the water quality standard) for mercury. Most of the load is from unidentified sources and may be due to atmospheric deposition. Phase 1 of this study consisted of twelve sampling events and included three wet weather events and two tidal cycle events (wet weather is defined as a rain event with more than 0.25 inch of precipitation; tidal cycle sampling involved the collection of four samples over the course of one tidal cycle). Data from the Phase I metals sampling program (see Table 2.12) showed that mercury levels did not exceed the water quality standard (WQS) for chronic ecological effects (0.025 μg/L) in Raritan Bay but the standard was exceeded on four different occasions in the Raritan River (GLEC 1996). For Newark Bay, the Hackensack, and Passaic Rivers, the mercury WQS was exceeded on all but four sampling dates: Newark Bay had exceedances of the WQS on 10 of 12 sampling dates and both the Passaic and Hackensack Rivers had exceedances on 11 of the 12 sampling dates. The mercury levels in the Passaic River were 15-35 times higher than the WQS (GLEC 1996) (Table 2.12).

The NJ Toxics Reduction Workplan, part of the HEP program, includes monitoring the loadings of suspended sediments and certain pollutants, including mercury, at the head-of-tide of major tributaries to the Harbor, within the tidal reaches of major and minor tributaries to the Harbor, and within the Newark Bay complex. These data will help locate significant local point sources of mercury such as combined sewer outfalls and municipal wastewater plants.

Table 2.12. Total Mercury Concentrations at Five Sites in the NY-NJ Harbor Estuary, June 15 through December 13, 1995 (GLEC 1996).

	Raritan Bay	**Raritan River**	**Newark Bay**	**Hackensack River**	**Passaic River**
Range (μg/L)	0.003-0.012	0.006-0.042	0.015-0.127	0.005-0.235	0.003-0.878
Mean (μg/L) ±S.D.	0.007±0.003	0.018±0.012	0.069±0.038	0.086±0.068	0.250±0.256
# Samples Exceeding 0.025 : g/L / Total # Samples	0/12	4/12	10/12	11/12	11/12
Percent of Samples Exceeding 0.025 : g/L	0	33%	83%	92%	92%

A 1984 survey of water quality in streams of Logan Township in Gloucester County, tributaries of the Delaware River, as defined in the Delaware Estuary Program, indicated that mercury concentrations were #0.1 μg/L. This exceeds the marine criteria for chronic ecological effects of 0.025 μg/L and the freshwater criteria for chronic ecological effects of 0.012 μg/L (Hochreiter and Kozinski 1985). The total loading of mercury to the water column of the Delaware Estuary is approximately 10,000 kg/yr (11 tons/yr) (Versar 1994: NJDEP 1996). Of the percent of total loading by toxic substances into the Delaware Estuary, mercury represents 0.9%. Of this, greater than 75% of percent loading of mercury by source is estimated to be due to atmospheric deposition (Sutton et al. 1996; Frithsen et al. 1995).

4. Potential impact of new dam construction in NJ on surface water mercury

Reservoir construction is known to increase available mercury, presumably by converting soil with trace amounts of inorganic mercury to sediment, in which biomethylation occurs, and/or as a result of increased bacterial activity following inundation (Gilmour & Capone 1987). This yields methylmercury which can biomagnify in the newly created aquatic food

chain. The age of reservoirs is an important determinant of mercury levels, with younger impoundments having elevated mercury concentrations.

Consistent with these observations, a study in NJ by the Academy of Natural Sciences (ANSP 1994) found that, after adjusting for fish length, pH, and type of waterbody, mercury concentrations were higher than predicted in fish collected from recently filled reservoirs (i.e., Manasquan and Merrill Creek reservoirs) than from other water bodies. Lower than predicted fish mercury concentrations were observed in small impoundments (e.g., Cooper River Park Lake, Newton Lake), small lakes, especially in the Coastal Plain portion of the State, and tidal sites (Delaware River above Camden, Rancocas Creek and Big Timber Creek).

5. Summary and Conclusions

In the Hudson-Raritan Estuary, the mercury levels in the water column were found to exceed (or nearly exceed) the ambient surface water quality criterion. Recent sampling has shown that while mercury did not exceed the water quality criterion in Raritan Bay, the mercury water quality criterion was exceeded in the Raritan River, Newark Bay and the Hackensack and Passaic Rivers. Mercury levels were 15-35 times higher than the water quality criterion in the Passaic River. In the Delaware Estuary there were also exceedances and it is estimated that 75% of the mercury comes from atmospheric deposition.

F. Mercury in Sediments

1. Freshwater Sediments

Sediment concentrations of mercury in isolated lakes subject only to long range atmospheric sources of mercury have mercury concentrations in the range of 0.04-0.24 μg/g (ATSDR 1999a). These values provide an estimate of the background sediment concentration in North America.

Some NJ lakes have been analyzed for sediment mercury concentrations. In Monmouth County, the local health department sampled nine lake sediments. The range of median sediment mercury concentrations reported was 0.07 -0.09 : g/g (ppm) (NJDEPE 1993). The average mercury concentrations in sediments of three lakes in NJ were 0.13 ± 0.05 : g/g (ppm) (Lake Assunpink), 0.21 ± 0.01 μg/g (Mountain Lake) and 0.35 ± 0.07 μg/g (Parvin Lake) (Stevenson et al. 1995). Thus, the mercury concentrations in sediment of this limited sample of NJ lakes and streams are generally in the range of the North American background. Nonetheless, the sediments of Mountain Lake and Parvin Lake are near the lower end of the range where ecological effects might be expected (Stevenson et al. 1995).

Sediment levels of mercury are monitored every three years as part of the NJDEP's Ambient Stream Monitoring Network (Fig. 2.4) and reported in the USGS Water Resources Data Reports. The data from this network have been used to assess the quality of freshwater streams and sediments. Table 2.13 summarizes information on mercury concentrations from this program.

Core studies reveal that surface sediments tend to have higher concentrations of mercury than deeper layers. Other than some limited studies, no comprehensive historic coring has been completed in NJ. However, such a study is now underway. On a national and regional basis, the USGS National Water Quality Assessment (NAWQA) Program is using radiochemical dating of sediment cores to evaluate historical trends in hydrophobic constituents (including

mercury) throughout the nation (USGS 1999). These include three sites in NJ: Clyde Potts Reservoir, Orange Reservoir, and Packanack Lake (Krabbenhoft 1999; Van Metre and Callendar 1997.

Table 2.13. Total Mercury Concentrations in Stream Sediments from the Ambient Stream Monitoring Network.

	1990-1997	**1998**
Average, μg/g	0.042	0.034
Median, μg/g	0.02	0.018
Range, μg/g	0.01-1.0	<0.01-0.35
# samples	168	22
# sites	73	22
Detection Limit, μg/g	0.01	0.01

Mercury concentrations in the Orange Reservoir sediment core were approximately 1 μg/g at the bottom (oldest portion) of the core; concentrations increased after 1951 to a current level of 5μg/g. The Clyde Potts Reservoir showed highly variable concentrations at the bottom of the core, while the remainder of the core was not; concentrations varied from 0.26 μg/g in 1973 to a maximum of 0.38 μg/g in 1992. Packanack Lack mercury sediment concentrations increased from 0.27 μg/g (1922-29) to a peak concentration of 0.66 μg/g (1944-48), followed by a decrease to current concentrations of approximately 0.45 μg/g.

a. Point Source Contamination of Sediment

There are a number of freshwater sediments, known to have become contaminated with mercury from specific discharges. The Pompton Lakes Works (PLW) used fulminate of mercury, $Hg(ONC)_2$ to manufacture explosives, and its discharges have contaminated Acid Brook, which flows through the facility and discharges to Pompton Lake, where it has formed a delta (i.e., Acid Brook delta). Acid Brook delta sediments have maximum levels of mercury of 1,450 ppm. This is discussed in more detail in Chapter 8, Sec. B.

b. Summary and Conclusions

Compared to surface and ground water, the database on mercury in freshwater sediments is very sparse. Based on these limited data, mercury levels in lake and stream sediments in some locations appear to be within the range of North American background. However, at some locations where specific mercury discharges have occurred, mercury levels in sediment greatly exceed background levels. Additional assessments are needed in terms of historic and current levels of mercury loadings to the sediments/soils on a statewide basis with a comparison to regional and local sources of mercury loadings.

2. Marine and estuarine sediments

a. New York-NJ Harbor Estuary

Data from the NY-NJ Harbor Estuary Program demonstrated that mercury exceeded the water quality criterion virtually harbor wide (NJDEP 1996). Mercury levels in sediments of the estuary exceed the NOAA Effects Range - Median (ER-M) Value of 0.71 μg/g (the level observed to cause adverse effects in biota with a 50% incidence). Mercury exceeds this value by ten times or more in the Hackensack River, Arthur Kill, and Newark Bay. Whereas undisturbed sediments may be a sink for mercury, dredging and other disturbances contribute

to resuspension of contaminants in sediments, possibly providing the opportunity for residual inorganic mercury to be methylated and enter the food chain.

The HEP indicated that municipal and industrial discharges of mercury in the Harbor are thought to contribute only a small portion of the total mercury load (NJDEP 1996). One or more large unidentified sources of mercury appear to account for most of the mercury deposition in the Harbor. Therefore, the HEP is attempting to track down the sources of various contaminants including mercury. The HEP CCMP (NJDEP 1996) committed to taking remedial action at selected contaminated sediment sites, including the Passaic River Study Area, and recommended assessment of additional areas of highly contaminated sediments in the Estuary.

Data from the 1995 Phase I sampling program conducted by the NJ Harbor Dischargers Group, indicate that sediment mercury concentrations in the Harbor varied among the five sites (Raritan Bay, Raritan River, Newark Bay, Hackensack River and Passaic River) with concentrations of mercury in the sediments ranging from 0.076-4.81 μg/g. The mercury concentrations were lowest in the Raritan River and highest in the Hackensack River (GLEC 1996).

On a regional basis in the Hudson Raritan watershed, the HEP, in coordination with EPA, completed a R-EMAP (Region Environmental Monitoring and Assessment Project) on baseline sediment quality of various basins within the Harbor (Adams et al. 1996). Surface sediment contaminant concentrations, two sediment toxicity tests (*Ampelisca abdita* and *Microtox μ*), and benthic macrofaunal community structure were measured at 168 sites during 1993-1994 in six sub-basins (Newark Bay, Lower Harbor, Upper Harbor, Jamaica Bay, western Long Island Sound, and the NY Bight Apex).

At least 75% of the Harbor area exceeded the lower range for possible effects on biota (ER-L) and 34% exceeding the ER-M for mercury in the sediments. Newark Bay was the most contaminated sub-basin, with 92% of its samples exceeding an ER-M concentration and 49% of its area showing a toxicological response (Adams et al. 1996). Based on comparisons with EPA's EMAP data from the Virginia Province during 1990-1993 (coastal area from Cape Cod to and including Chesapeake Bay), samples from the Harbor area represent 69% of all samples exceeding the ER-M, even though the Harbor contributed only 4% of the sediments sampled in the Virginian Province (Adams et al. 1996).

There are several sites in the NY Harbor where sediment contamination originates from specific industrial discharges of mercury. Berry's Creek in the Hackensack Meadows is highly contaminated by discharges from the former Ventron plant. Pierson's Creek located in Newark has been highly contaminated with a number of contaminants including mercury from the Troy Chemical site (both are described in more detail in Chapter 8, Section B). Average concentrations of mercury in surface sediments along the six mile reach of the Passaic River study area (including the Diamond Alkalai Superfund Site, were 2.1 ppm (452 samples) with a range of 0.005 to 15 ppm (NOAA 1999). In contrast, sediments at 0.5 - 6 meters depth exhibited a higher average concentration (9.4 ppm) and range (0.11 ppm to 29.6 ppm). These average mercury levels greatly exceed sediment benchmarks for ecological effects (ER-M of 0.71 mg/kg) thereby posing a high risk of adverse effects to aquatic biota.

The NJ Toxics Reduction Workplan (NJDEP 1999), part of the HEP program, includes ambient monitoring of the loadings of suspended sediments and chemicals of concern, including mercury, at the head-of-tide of major tributaries to the Harbor, within the tidal reaches of major and minor tributaries to the Harbor, and within the Newark Bay complex. These data will help identify those tributaries where upstream, major and minor tributary

sources contribute significant loadings of chemicals of concern. The fate and transport of suspended sediment and contaminants will be evaluated. A longer-term effort that includes monitoring to assess mercury partitioning and fate, reassessment of loads and appropriate modeling, is needed.

a. Delaware Estuary

The Delaware Estuary Program (DELEP) report, "The Scientific Characterization of the Delaware Estuary" (Sutton et al. 1996) indicates that "…urban runoff, point sources, atmospheric deposition, and ground water all contribute significant amounts of mercury to the estuary". The total input of mercury is approximately 10,000 kg/year (ca. 11 tons/year; Frithsen et al. 1995). The significant sources include atmospheric deposition (80%), urban runoff (10%) and point sources (10%) (Frithsen et al. 1995).

The DELEP identified mercury on its preliminary listing of toxic pollutants based on sediment contamination and possible exceedances of chronic aquatic life water quality criteria; 24 point source discharges were listed as possible sources along with unidentified nonpoint sources. Costa and Sauer (1994) reported that sediment samples obtained in July 1971 between River Miles 80 and 115 (approximately Brandywine Creek north to the Rancocas Creek) ranged from < 0.20 to 0.5 ppm, all exceeding the ER-L. Their data is shown in Figure 2.6.

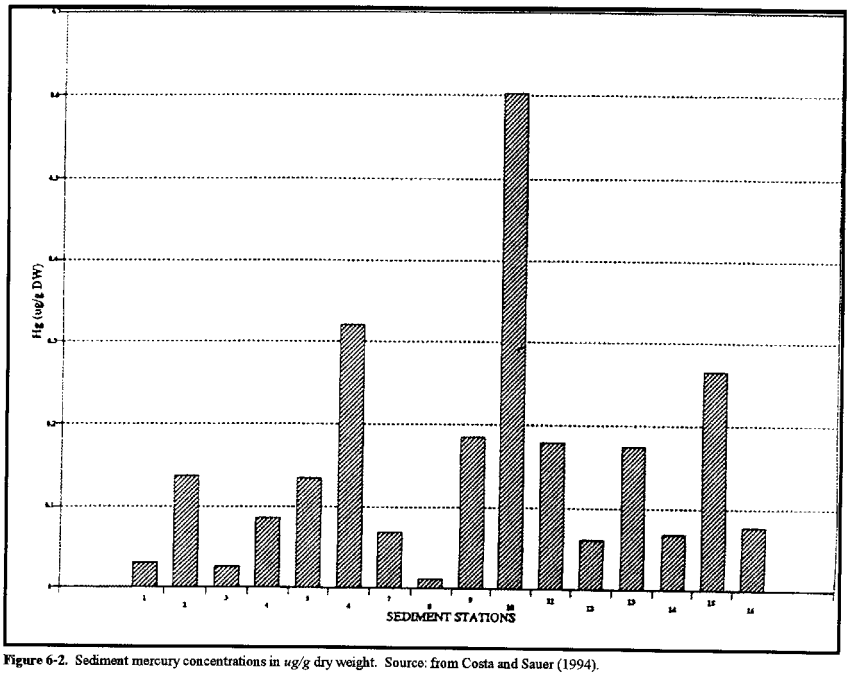


Figure 6-2. Sediment mercury concentrations in *ug/g* dry weight. Source: from Costa and Sauer (1994).

Provisional data from the Mid-Atlantic Integrated Assessment (MAIA) of sampling locations in Delaware Bay and vicinity in 1997 indicated that most of the lower Delaware Bay had mercury concentrations below the ER-L of 0.15 µg/g (dry wt) while concentrations from Camden northward ranged up to 1.88 µg/g .

b. Summary and Conclusions

In estuarine systems, elevated levels of mercury are found throughout the sediments of the Hudson-Raritan Estuary and in the upper Delaware Estuary. In addition, there are well-documented sources of site specific mercury contamination in estuaries. Mercury in water, sediments, and biota in these estuaries has been identified as a chemical of concern and the NY-NJ HEP is conducting extensive monitoring as part of the Toxics Source Reduction Plans in NY and NJ to address this problem. At least 75% of the NY-NJ Harbor sediments exceeded the lower concentration corresponding to a presumed threshold for effects on biota (ER-L), and many exceeded the ER-M as well.

G. Mercury in Soil

A study of concentrations of contaminants in NJ soils was carried out to support hazardous site cleanup efforts (Fields et al. 1993). The study provides data on the soil concentration of mercury by land use and soil type and is assumed to be reasonably representative. A total of 80 soil samples was collected throughout the state. Thirty-five of the samples were collected from rural, undisturbed areas of the state, and 37 samples were collected from urban (19) and suburban (18) parks in areas representing a broad range of population densities. Several additional samples were collected from golf course greens (5) and agricultural land (3). Table 2.14 shows the results for total mercury.

Table 2.14. Background Concentration of Total Mercury in NJ Soils.

Land or Soil Type	Minimum, mg/kg (μg/g=ppm)	Median, mg/kg	Maximum, mg/kg	Citation
Urban	< 0.01	0.31	2.71	Fields et al. 1993
Suburban	< 0.01	0.06	0.19	Fields et al. 1993
Rural	< 0.01	< 0.01	0.26	Fields et al. 1993
Golf	1.40	5.00	7.70	Fields et al. 1993
Farm	< 0.01	< 0.01	< 0.01	Fields et al. 1993

For comparison, Table 2.15 shows background soil concentrations of mercury reported in other states and the corresponding clean-up standards (levels above which remediation is required). Soil clean-up levels vary from state to state, depending upon the basis for criteria development, and many states differentiate between residential land use standards and industrial/commercial standards.

Table 2.15. Background Soil Concentrations of Mercury by State and Their Corresponding Clean-up Levels (mg/kg=：g/g=ppm).

	Mercury ppm (mg/kg) background	Clean-up level for mercury (mg/kg)
Arizona	0.1	*
California	0.26	*
Connecticut	*	*
Delaware	0.2-0.3	7.8 (residential) 610 (nonresidential)
Georgia	0.5	0.5
Idaho	*	Background
Illinois	<0.01-1.67 (0.11 mean; 0.06 median)	23 (residential) 610 (industrial/commercial)
Kentucky	0.5	*
Massachusetts	0.3	20
Mississippi	*	24

Missouri	*	17
Montana	0.05-0.18	*
NJ	<0.01-2.71	14 (residential)
New York	0.001-0.2	*
Oregon	*	80
Rhode Island	*	23
Vermont	0.876±0.457	*
South Carolina	*	6.7 (residential) 180 (nonresidential)
Texas	*	0.2
Washington	0.02-0.13	*

* Information not available or not known.

1. Summary and Conclusions

It appears that, except for golf courses, background soil concentrations of mercury in NJ are generally low, with levels in urban areas higher than those in suburban and rural areas. Based on sparse data, the highest levels in areas not specifically considered to be contaminated sites appear to occur in golf course soil. This may reflect historical use of mercury-containing pesticides. Although comparisons are difficult, background mercury levels in NJ soil appear to be roughly comparable to background levels measured in other states.

Recommendations

Consider establishing the mercury-contaminated sites in the Berry's Creek area as an Environmental Research Park, patterned on the National Environmental Research Park system. This could serve as a resource for studies and monitoring of the complex processor governing the fate and transport of mercury in both the terrestrial and estuarine environment (from Recommendation M.5 in Volume 1).

Expand and maintain a statewide ground water monitoring program for mercury (from Recommendation O.1. in Volume 1). Additional private wells should be sampled for mercury and the samples should be speciated to determine the occurrence of volatile (elemental) mercury. In-house sampling should be undertaken to determine the actual exposures to volatile mercury from showering.

Upgrade procedures used in all monitoring programs to include state-of-the-art analytical methods to provide lower detection limits for mercury and mercury speciation (from Recommendation M.1. in Volume 1). Data on mercury concentration and occurrence in NJ freshwater streams should be generated, compiled and reported as direct numerical values rather than as categorical exceedances so as to provide the greatest utility in interpretation. Data analysis should be expanded to allow assessment of the potential for chronic impacts on aquatic life.

The sampling of NJ waters should be continued and expanded using methodologies that are appropriate for comparison to the water quality standards for protection of aquatic life and for human health.

Since sediment is the crucial environment in which biomethylation takes place, research should focus on understanding and possibly modifying the processes in different kinds of NJ waters.

The Ambient Stream Monitoring program should be continued and a subset of samples should have mercury speciation performed. A lake monitoring network should likewise be established.

Establish a monitoring network for marine and estuarine sediments in the NY-NJ Harbor Estuary as well as in other NJ marine and estuarine waters.